

Form Approved  
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)

2. REPORT DATE

### 3. REPORT TYPE AND DATES COVERED

6 Mar 90

FINAL 01 Sep 87 to 31 Dec 89

**TITLE AND SUBTITLE**

## AUDITORY PERCEPTION OF COMPLEX SOUNDS

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**5. FUNDING NUMBERS**

G - AFOSR-87-0382

PE - 61102F

PR - 2313

TA - A6

**8. PERFORMING ORGANIZATION  
REPORT NUMBER**

APOS.R. TR. 90 - 0360

**. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)**

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AFOSR/NL, BDA 410  
Bolling AFB, DC 20332

10. SPONSORING / MONITORING  
AGENCY REPORT NUMBER

AFOSR-87-0382

## 11. SUPPLEMENTARY NOTES

## 12a. DISTRIBUTION / AVAILABILITY STATEMENT

unlimited

## 12b. DISTRIBUTION CODE

## 13. ABSTRACT (Maximum 200 words)

Experiments on auditory perception of temporal interval, pitch, and timbre are outlined. REference to more detailed articles in press are provided. Articles on auditory timing have appeared in Perception & Psychophysics, (1990), Vol 47(3), pp215-226 and 227-242.

Accession For	
WTIS GRA&I	<input checked="" type="checkbox"/>
WTIC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	
By	
Distribution/	
Availability Codes	
Avail and/or	
Special	
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DTIC  
ELECTE  
MAR 29 1990

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#### 14. SUBJECT TERMS

## 19. NUMBER OF PAGES

## 16. PRICE CODE

**17. SECURITY CLASSIFICATION OF REPORT**

## 18. SECURITY CLASSIFICATION OF THIS PAGE

**19. SECURITY CLASSIFICATION OF ABSTRACT**

## 20. LIMITATION OF ABSTRACT

**AD-A219 927**

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Feb 25, 1990

Final Technical Report AFOSR 87-0382      Ira J Hirsh - PI  
1 September 1987- 30 September 1989, extended to 31 December 1989

## AUDITORY PERCEPTION OF COMPLEX SOUNDS

This Final Technical Report covers the period 1 September 1988 to 31 December 1989. The first year was previously reported on in February, 1989 in the first Annual Technical Report. Therefore the present document concentrates on work accomplished in the second year, extended to a 15-month period ending 31 December 1989.

### 1. SUMMARY

#### Interval timing.

Following earlier experiments (see Hirsh et al, 1990; Monahan and Hirsh, 1990) we have generated temporal patterns whose level of complexity was enhanced to include changes of loudness or pitch. In an adaptive procedure, listeners discriminated the delay of a single tone in otherwise isochronic six-tone patterns. The temporal DL for delay was measured at three tempos (inter-onset intervals of 50, 100, 200 msec) and at four delay positions (tones 2 through 5). The patterns of a first experiment were composed of loud (forte) and soft (piano) tones; thus FFPFPP, PFPFPP, etc. where F was 80 dB and P was 70 dB. In a second experiment the parallels of these patterns were composed of high(H) and low(L) frequencies. On both studies, the global measure of timing accuracy was similar to that found in earlier literature on single intervals, namely 5-8% at 200 msec, 9-15% at 100 msec, 15-25% at 50 msec inter-onset intervals. Primarily at 50 msec, earlier positions of delay were discriminated less well for loudness patterns. Timing accuracy was slightly better for loud tones than for soft at the faster tempos. In the pitch patterns, timing accuracy was better for delayed tones followed by tones of the same frequency rather than of different frequency. (These studies were presented to the 118th meeting of the Acoustical Society of America in November, 1989, and are being prepared for publication.)

A final study concerns patterns of tones in which the inter-onset intervals separating successive tones are chosen at random from sets of intervals around average values of 50, 100 and 200 msec. Results of this study are being analyzed and will be reported in a manuscript to be prepared for publication.

#### Pitch and timbre.

The dual nature of pitch ("spectral"/ "virtual") and its relation to such timbral concepts as "sharpness" and "roughness" was explored in experiments designed to ascertain perceptual cues facilitating discrimination of complex tones with flat spectral envelopes. Three types of complexes were employed: (1) harmonic "residue" tones comprising 4 harmonics, (2) ten-component harmonic and inharmonic complexes with all components shifted up or down from some reference frequency, and (3) ten-component complexes with a single component shifted away from its harmonic frequency. Using two-tone sequences as stimuli, listeners were asked to judge if the second tone was: 1) the same, 2) higher in pitch, 3) lower in pitch, 4) different in "something else" but

not pitch, 5) different in "something else" and higher, or 6) different in "something else" and lower in pitch, than the first tone. ("Something else" is taken to be synonymous with "timbre").

For residue tones, the data indicate that changes in spectral locus yield changes in timbre. Further, direction of locus change can indicate pitch change, despite little or no change in F0 (0%-2% for 200- and 400-Hz F0). This implies that changes in timbral "sharpness" may be construed as pitch changes, given the absence of other cues. For stimuli in which components are shifted from harmonic frequencies, the unitary percept of a complex may be replaced by one of multiple sources. Low components (n=1-3) are more susceptible to being "heard out" as individual entities, while changes in higher components may yield changes in timbre, such as "roughness". Thus, comparisons of components based on factors such as (1) magnitude, (2) location and (3) direction of spectral change in a sequence can guide grouping operations, in addition to indicating changes in an overall property of a complex as a whole, such as its pitch, timbre, or both of these percepts simultaneously.

The results of these experiments were reported in a special session on "Timbre" at the 118th meeting of the Acoustical Society of America in November 1989. They also comprise P. Singh's doctoral dissertation, to be completed in the spring, 1990 semester at Washington University. Publication will follow, including appropriate acknowledgement of support.

## 2. PERSONNEL

There were no changes in personnel during this second year. Three investigators continued: Ira J. Hirsh, PI; Caroline B. Monahan, Postdoctoral Research Scientist; and Punita G. Singh, Graduate Research Assistant. (During the extension period from October 1 to 31 December, 1989, Drs. Hirsh and Monahan continued the work without further compensation from the Air Force grant.)

## 3. FACILITIES AND EQUIPMENT

There were no changes in the space allocated or the equipment used. Additional programming was provided by Central Institute.

## 4. PUBLICATIONS

The following publications have resulted from the two- year (28 months) period. The first three were listed in last year's Annual Technical Report.

Singh, P.G. (1987) "Perceptual organization of complex-tone sequences: A tradeoff between pitch and timbre?" J.Acoust.Soc.Amer., 82:886-899.

Monahan, C.B. ( ) "Parallels in rhythm and melody." In W.J.Dowling and T.J.Tighe (Eds), The Understanding of Melody and Rhythm. Potomac, Md: Erlbaum.

Fourakis, M. and Monahan, C.B. (1988) "Effects of metrical foot structure on syllable timing." Language and Speech, 31:283-306.

Hirsh, I.J., Monahan, C.B., Grant, K.W., and Singh, P.G. (1990) "Studies in auditory timing: 1. Simple patterns" Perception and Psychophysics, 47:215-226.

Monahan, C.B. and Hirsh, I.J. (1990) "Studies in auditory timing: 2. Rhythmic patterns" Perception and Psychophysics 47:227-242.